PB-241 177

UNION LAKE, BRANCH COUNTY, MICHIGAN

Pacific Northwest Environmental Research Laboratory

Prepared for:

National Environmental Research Center

March 1975

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	PB 241 177
4. TITLE AND SUBTITLE Report on Union Lake, Branch County, Michigan		5. REPORT DATE Prepared March 1975 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Anonymous (National Eutrophication Survey Staff)		8. PERFORMING ORGANIZATION REPORT NO. Working Paper # 216
9. PERFORMING ORGANIZATION NAME AND ADDRESS Pacific Northwest Environmental Research Laboratory U.S.Environmental Protection Agency 200 S. W. 35th St. Corvallis, Oregon 97330		10. PROGRAM ELEMENT NO. 1BA029 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Office of Research and Development U.S. Environmental Protection Agency 401 M Street, S. W. Washington, DC 20460		13. TYPE OF REPORT AND PERIOD COVERED Final - 1972 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES
Prepared in cooperation with the U.S. Environmental Protection Agency, National Environmental Research Center, Las Vegas, Nevada 89114

16. ABSTRACT
Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivded according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
eutrophication lakes nutrients phosphorus nitrogen loading		05B 05C

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
US Department of Commerce
Springfield, VA. 22151

PRICES SUBJECT TO CHANGE

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release unlimited		37
	20. SECURITY CLASS *(This page)*	22. PRICE $3.75/2.25

EPA Form 2220-1 (9-73)

CONTENTS

	Page
Foreword	ii
List of Michigan Study Lakes	iv
Lake and Drainage Area Map	v
Sections	
I. Conclusions	1
II. Lake and Drainage Basin Characteristics	4
III. Lake Water Quality Summary	5
IV. Nutrient Loadings	10
V. Literature Reviewed	15
VI. Appendices	16

FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Michigan Department of Natural Resources for professional involvement and to the Michigan National Guard for conducting the tributary sampling phase of the Survey.

A. Gene Gazlay, former Director, and David H. Jenkins, Acting Director, Michigan Department of Natural Resources; Carlos Fetterolf, Chief Environmental Scientist, Bureau of Water Management; and John Robinson, Chief, Dennis Tierney, Aquatic Biologist, and Albert Massey, Aquatic Biologist, Water Quality Appraisal Section, Bureau of Water Management, Department of Natural Resources, provided invaluable lake documentation and counsel during the course of the Survey. John Vogt, Chief of the Bureau of Environmental Health, Michigan Department of Public Health, and his staff were most helpful in identifying point sources and soliciting municipal participation in the Survey.

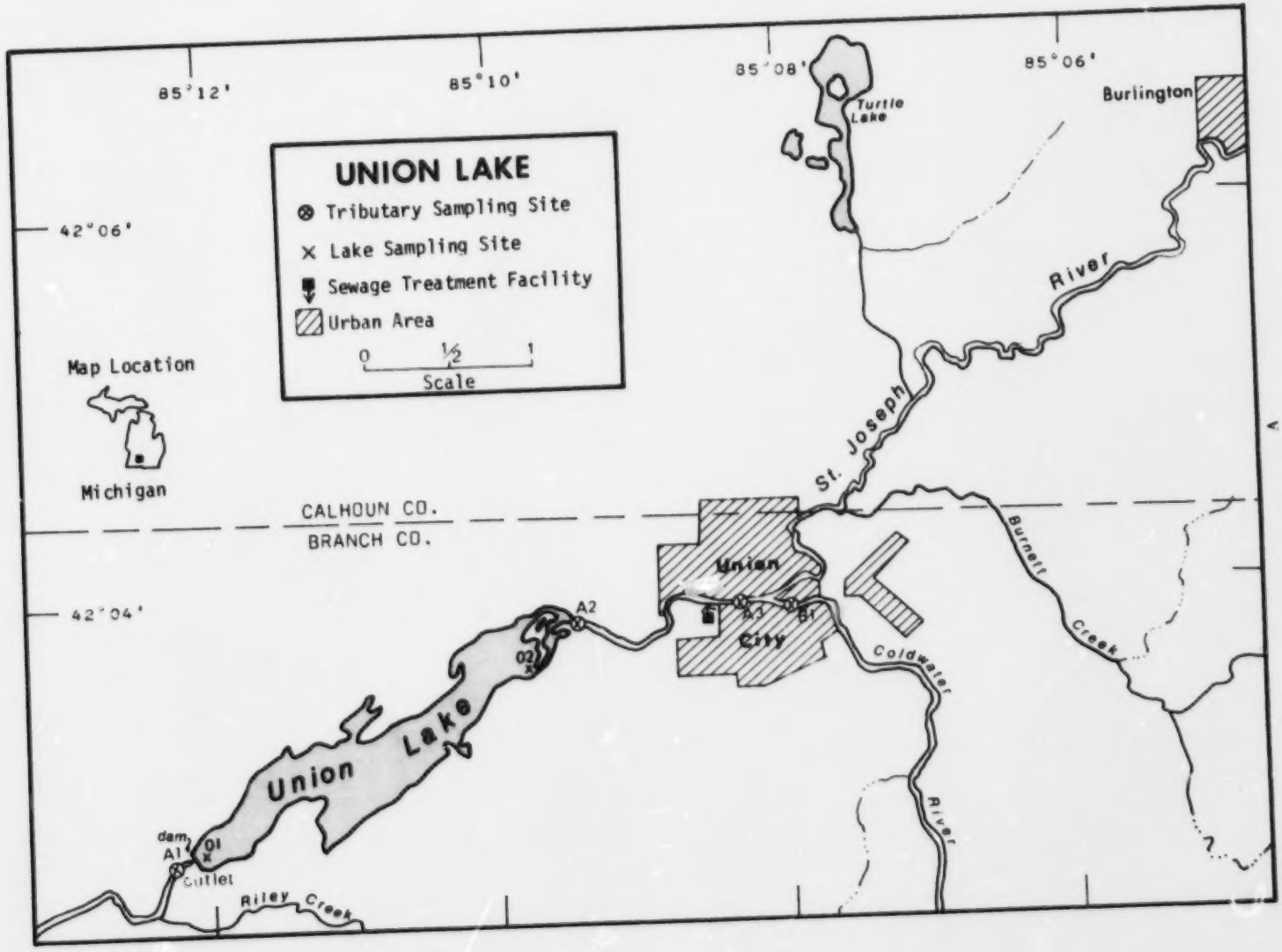
Major General Clarence A. Schnipke (Retired), then the Adjutant General of Michigan, and Project Officer Colonel Albert W. Lesky, who directed the volunteer efforts of the Michigan National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF MICHIGAN

LAKE NAME	COUNTY
Allegan Res.	Allegan
Barton	Kalamazoo
Belleville	Wayne
Betsie	Benzie
Brighton	Livingston
Caro Res.	Tuscola
Charlevoix	Charlevoix
Chemung	Livingston
Constantine Res.	St. Joseph
Crystal	Montcalm
Deer	Marquette
Ford	Washtenaw
Fremont	Newago
Higgins	Roscommon
Holloway Res.	Genesee, Lapeer
Houghton	Roscommon
Jordon	Ionia, Barry
Kent	Oakland
Long	St. Joseph
Macatawa	Ottawa
Manistee	Manistee
Mona	Muskegon
Muskegon	Muskegon
Pentwater	Oceana
Pere Marquette	Mason
Portage	Houghton
Randall	Branch
Rogers Pond	Mecosta
Ross	Gladwin
St. Louis Res.	Gratiot
Sanford	Midland
Strawberry	Livingston
Thompson	Livingston
Thornapple	Barry
Union	Branch
White	Muskegon


UNION LAKE
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
Urban Area
0 ½ 1
Scale
Map Location
Michigan
85°12'
85°10'
85°08'
85°06'
42°06'
42°04'
CALHOUN CO.
BRANCH CO.
Turtle Lake
Burlington
St. Joseph River
Union City
Union Lake
Coldwater River
Burnett Creek
Riley Creek
dam
Outlet
A1
A2
A3
B1
01
02

UNION LAKE

STORET NO. 2685

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Union Lake is eutrophic. Of the 35 Michigan lakes sampled in November when essentially all were well-mixed, 20 had less mean total phosphorus, 25 had less mean dissolved phosphorus, and 25 had less mean inorganic nitrogen; of all 41 lakes sampled, 27 had less mean chlorophyll a, and 25 had greater mean Secchi disc transparency*.

Survey limnologists indicated that the lake was moderately turbid and without visible algal blooms during any of the sampling periods.

B. Rate-Limiting Nutrient:

Based on the results of the algal assay, Union Lake was phosphorus limited at the time the sample was taken (09/16/72). The lake data also indicate that phosphorus was limiting (i.e., all N/P ratios were 16/1 or greater).

C. Nutrient Controllability:

1. Point sources--During the sampling year, Union Lake received a total phosphorus load at a rate nearly four times the rate proposed by Vollenweider (in press) as "dangerous";

---

* See Appendix A.

i.e., a eutrophic rate (see page 14). However, Vollenweider's model probably does not apply to water bodies with short hydraulic retention times, and the mean hydraulic retention time of Union Lake is a very short two days.

It is estimated that Union City contributed 10% of the total phosphorus load to Union Lake during the sampling year. While even complete removal of phosphorus at this source would still leave a loading rate a little over three times the eutrophic rate, in view of the very short hydraulic retention time of Union Lake, it is likely that a high degree of phosphorus removal at the Union City wastewater treatment plant would at least reduce the incidence and severity of nuisance algal blooms.

2. Non-point sources (see page 14)--The phosphorus export of the St. Joseph River was somewhat high during the sampling year. However, most of this phosphorus load was contributed by the Coldwater River.

Based on the phosphorus concentrations measured in the Coldwater River at station B-1 (see map, page v) and the mean U.S.G.S. flow of ten years of record near Hodunk, MI* (about 3.5 miles upstream from B-1), it is calculated that the Coldwater River contributed about 28,400 pounds of phosphorus to the system. This

* U.S.G.S. Water Resources Data for Michigan--Surface Water Records, 1972, pg. 69.

is about 73% of the non-point phosphorus load attributed to the St. Joseph River at the inlet to Union Lake (station A-2).

It is believed that the high Coldwater River phosphorus export is largely due to two known point sources beyond the 25-mile limit of the Survey*, and it appears that if a marked improvement in the trophic condition of Union Lake is to be achieved, all phosphorus inputs will have to be minimized to the greatest practicable degree.

* See Working Paper No. 1, "Survey Methods, 1972".

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

A. Lake Morphometry†:

1. Surface area: 525 acres.
2. Mean depth: 2.8 feet.
3. Maximum depth: 16 feet.
4. Volume: 1,470 acre-feet.
5. Mean hydraulic retention time: 2 days.

B. Tributary and Outlet:
(See Appendix B for flow data)

1. Tributaries -

Name	Drainage area*	Mean flow*
St. Joseph River	530.0 mi^2	375.1 cfs
Minor tributaries & immediate drainage -	3.2 mi^2	2.9 cfs
Totals	533.2 mi^2	378.0 cfs

2. Outlet -

St. Joseph River	534.0 mi^2**	378.0 cfs**

C. Precipitation***:

1. Year of sampling: 37.1 inches.
2. Mean annual: 34.1 inches.

---

† MI Dept. Cons. lake inventory map (1963); mean depth by random-dot method.
* Drainage areas are accurate within ±5%; mean daily flows for 74% of the sampling sites are accurate within ±25% and the remaining sites up to ±40%; and mean monthly flows, normalized mean monthly flows, and mean annual flows are slightly more accurate than mean daily flows.
** Includes area of lake; outflow adjusted to equal sum of inflows.
*** See Working Paper No. 1, "Survey Methods, 1972".

III. LAKE WATER QUALITY SUMMARY

Union Lake was sampled three times during the open-water season of 1972 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from two stations on the lake and from a number of depths at each station (see map, page v). During each visit, a single depth-integrated (near bottom to surface) sample was composited from the two stations for phytoplankton identification and enumeration; and during the second visit, a single five-gallon depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 14 feet at station 1 and 12 feet at station 2.

The results obtained are presented in full in Appendix C, and the data for the fall sampling period, when the lake essentially was well-mixed, are summarized below. Note, however, the Secchi disc summary is based on all values.

For differences in the various parameters at the other sampling times, refer to Appendix C.

A. Physical and chemical characteristics:

FALL VALUES

(11/12/72)

Parameter	Minimum	Mean	Median	Maximum
Temperature (Cent.)	6.9	6.9	6.9	7.0
Dissolved oxygen (mg/l)	10.0	10.0	10.0	10.0
Conductivity (μmhos)	540	540	540	540
pH (units)	7.8	7.9	7.9	7.9
Alkalinity (mg/l)	196	207	203	226
Total P (mg/l)	0.073	0.083	0.083	0.095
Dissolved P (mg/l)	0.053	0.064	0.061	0.079
NO_2 + NO_3 (mg/l)	0.940	0.945	0.940	0.960
Ammonia (mg/l)	0.280	0.307	0.315	0.320
		ALL VALUES		
Secchi disc (inches)	30	45	36	72

B. Biological characteristics:

1. Phytoplankton* -

Sampling Date	Dominant Genera	Number per ml
09/16/72	1. Anabaena	11,114
	2. Synedra	858
	3. Cyclotella	813
	4. Scenedesmus	452
	5. Microcystis	422
	Other genera	2,124
	Total	15,783
11/12/72	1. Dinobryon	1,407
	2. Flagellates	1,306
	3. Fragilaria	754
	4. Cyclotella	578
	5. Kirchneriella	327
	Other genera	2,412
	Total	6,784

* The June sample was lost in shipment.

2. Chlorophyll a -
(Because of instrumentation problems during the 1972 sampling, the following values may be in error by plus or minus 20 percent.)

Sampling Date	Station Number	Chlorophyll a (µg/l)
06/14/72	01	26.7
	02	34.6
09/16/72	01	3.7
	02	22.6
11/12/72	01	5.2
	02	1.2

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.004	0.553	2.7
0.010 P	0.014	0.553	7.1
0.020 P	0.024	0.553	10.6
0.050 P	0.054	0.553	11.5
0.050 P + 5.0 N	0.054	5.553	20.9
0.050 P + 10.0 N	0.054	10.553	20.8
10.0 N	0.004	10.553	2.5

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity of Union Lake was moderately high at the time the assay sample was collected. Also, increasing yields with increasing increments of orthophosphorus show that the system was limited by phosphorus at that time. Note that the addition of

nitrogen only resulted in a yield not significantly different from the control yield.

Phosphorus limitation is further substantiated by the lake data. At all sampling times, the nitrogen to phosphorus ratios were 16 to 1 or greater.

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Michigan National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of April and May when two samples were collected. Sampling was begun in October, 1972, and was completed in September, 1973.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Michigan District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Since no unimpacted Union Lake tributaries were sampled, nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated by using the means of the nutrient loads, in $lbs/mi^2/year$, at station B-1 of Mud Creek, tributary to nearby Randall Lake**, and multiplying by the ZZ area in mi^2.

Union City did not participate in the Survey, and nutrient loadings were estimated at 2.5 lbs P and 7.5 lbs N per capita per year.

---

* See Working Paper No. 1.
** Working Paper No. 207.

In the following tables, the loads attributed to the St. Joseph River are those measured at station A-2 minus the estimated Union City loads.

A. Waste Sources:

1. Known municipal† -

Name	Pop. Served	Treatment	Mean Flow (mgd)	Receiving Water
Union City	1,740*	lagoon w/seepage	0.174**	groundwater to St. Joseph River

2. Known industrial - None

† Eyer, 1973.
* 1970 Census.
** Estimated at 100 gal/capita/day.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
St. Joseph River	38,820	89.4
b. Minor tributaries & immediate drainage (non-point load) -	120	0.3
c. Known municipal STP's -		
Union City	4,350	10.0
d. Septic tanks* -	40	0.1
e. Industrial - Unknown	-	-
f. Direct precipitation** -	80	0.2
Total	43,410	100.0

2. Outputs -

Lake outlet - St. Joseph River 38,900

3. Net annual P accumulation - 4,510 pounds

* Estimate based on 61 shoreline dwellings; see Working Paper No. 1.
** See Working Paper No. 1.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	lbs N/ yr	% of total
a. Tributaries (non-point load) -		
St. Joseph River	1,401,290	97.6
b. Minor tributaries & immediate drainage (non-point load) -	14,310	1.0
c. Known municipal STP's -		
Union City	13,050	0.9
d. Septic tanks* -	1,430	0.1
e. Industrial - Unknown	-	-
f. Direct precipitation** -	5,060	0.4
Total	1,435,140	100.0

2. Outputs -

Lake outlet - St. Joseph River 1,419,340

3. Net annual N accumulation - 15,800 pounds

* Estimate based on 61 shoreline dwellings; see Working Paper No. 1.
** See Working Paper No. 1.

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	lbs P/mi^2/yr	lbs N/mi^2/yr
St. Joseph River	73	2,644

E. Yearly Loading Rates:

In the following table, the existing phosphorus loading rates are compared to those proposed by Vollenweider (in press). Essentially, his "dangerous" rate is the rate at which the receiving waters would become eutrophic or remain eutrophic; his "permissible" rate is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic rate would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with very short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
Units	Total	Accumulated	Total	Accumulated
lbs/acre/yr	82.7	8.6	2,733.6	30.1
grams/m^2/yr	9.27	0.96	306.4	3.4

Vollenweider loading rates for phosphorus (g/m^2/yr) based on mean depth and mean hydraulic retention time of Union Lake:

"Dangerous" (eutrophic rate)	2.40
"Permissible" (oligotrophic rate)	1.20

V. LITERATURE REVIEWED

Eyer, Frederick T., 1973. Treatment plant questionnaire (Union City STP). MI Dept. Nat. Resources, Lansing.

Vollenweider, Richard A. (in press). Input-output models. Schweiz. Z. Hydrol.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	----------FALL VALUES---------- MEAN TOTAL P	MEAN DISS P	MEAN INORG N	----------ALL VALUES---------- SDD- MEAN SEC	MEAN CHLORA	15- MIN UD
2640	HOLLOWAY RESERVOIR	0.062	0.043	1.481	439.375	18.678	9.200
2641	CARO RESERVOIR	0.117	0.022	3.835	473.000	11.967	9.500
2642	BOARDMAN HYDRO POND	0.006	0.005	0.358	363.500	1.267	6.600
2643	ALLEGAN LAKE	0.123	0.057	1.168	470.222	20.311	12.600
2644	BARTON LAKE	0.121	0.086	1.489	456.167	27.800	14.850
2649	BELLEVILLE LAKE	0.118	0.040	1.428	485.250	28.262	8.200
2650	BETSIE LAKE	0.025	0.008	0.273	481.667	4.567	7.400
2653	BRIGHTON LAKE	0.109	0.073	1.015	456.800	44.233	7.500
2657	LAKE CHARLEVOIX	0.007	0.006	0.230	351.250	3.800	9.240
2658	LAKE CHEMUNG	0.044	0.014	0.132	404.333	13.483	14.800
2661	CONSTANTINE RESERVOIR	0.027	0.008	0.910	456.167	39.317	7.500
2669	FORD LAKE	0.105	0.058	1.536	456.167	14.733	14.000
2671	FREMONT LAKE	0.372	0.242	1.406	441.667	28.500	14.800
2680	JORDAN LAKE	0.188	0.144	1.998	427.667	28.517	14.900
2683	KENT LAKE	0.040	0.015	0.417	495.000	33.944	13.000
2688	LAKE MACATAWA	0.197	0.120	2.358	477.600	25.600	12.200
2689	MANISTEE LAKE	0.018	0.010	0.304	491.333	6.317	11.360
2690	MUSKEGON LAKE	0.087	0.043	0.469	436.444	9.511	14.800
2695	PENTWATER LAKE	0.027	0.017	0.496	438.667	16.883	14.800
2671	RANDALL LAKE	0.246	0.183	0.818	457.333	27.217	8.020
2672	ROGERS POND	0.026	0.015	0.183	435.500	8.133	9.000
2673	RUSS RESERVOIR	0.034	0.021	0.468	485.333	10.383	8.200
2674	SANFORD LAKE	0.016	0.008	0.307	458.750	13.791	8.300
2683	THORNAPPLE LAKE	0.042	0.032	1.737	442.833	14.650	10.800
2685	UNION LAKE	0.083	0.064	1.252	455.500	15.667	8.200
2688	WHITE LAKE	0.027	0.019	0.367	417.778	9.211	13.400
2691	MONA LAKE	0.307	0.241	0.963	451.667	27.783	14.100
2692	LONG LAKE	0.163	0.148	0.749	418.400	10.067	13.600

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	FALL VALUES MEAN TOTAL P	FALL VALUES MEAN DISS P	FALL VALUES MEAN INORG N	ALL VALUES 500- MEAN SEC	ALL VALUES MEAN CHLORA	ALL VALUES 15- MIN DO
2693	ST LOUIS RESERVOIR	0.134	0.093	1.227	462.667	5.583	8.420
2694	CHYSTAL LAKE	0.009	0.006	0.164	380.000	2.986	13.000
2695	HIGGINS LAKE	0.007	0.005	0.058	268.500	1.043	9.400
2696	HOUGHTON LAKE	0.018	0.008	0.136	420.833	9.217	8.200
2697	THOMPSON LAKE	0.043	0.029	0.436	407.889	11.967	14.800
2698	PERE MARQUETTE LAKE	0.032	0.024	0.146	448.667	11.833	8.600
2699	STRAWBERRY LAKE	0.069	0.058	0.567	419.800	11.117	13.600

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	ALL VALUES: MEAN TOTAL P	ALL VALUES: MEAN DISS P	ALL VALUES: MEAN INORG N	ALL VALUES: SEC-MEAN SEC	ALL VALUES: MEAN CHLOPA	ALL VALUES: IS-MIN DO	NUMBER NO
2640	HOLLOWAY RESERVOIR	46 (16)	43 (15)	17 (6)	57 (20)	60 (21)	63 (22)	286
2641	CARO RESERVOIR	29 (10)	54 (19)	0 (0)	3 (1)	49 (17)	54 (19)	189
2642	BOARDMAN HYDRO POND	97 (34)	97 (34)	69 (24)	91 (32)	94 (33)	97 (34)	545
2643	ALLEGAN LAKE	20 (7)	31 (11)	31 (11)	6 (2)	29 (10)	40 (14)	157
2646	BARTON LAKE	23 (8)	20 (7)	14 (5)	29 (9)	14 (5)	3 (1)	103
2649	BELLEVILLE LAKE	26 (9)	37 (13)	20 (7)	11 (4)	11 (4)	79 (26)	184
2650	BETSIE LAKE	77 (27)	77 (27)	80 (28)	17 (6)	86 (30)	94 (33)	431
2653	BRIGHTON LAKE	31 (11)	23 (8)	34 (12)	34 (12)	0 (0)	90 (31)	212
2657	LAKE CHARLEVOIX	91 (32)	91 (32)	83 (29)	94 (33)	89 (31)	60 (21)	508
2658	LAKE CHEMUNG	49 (17)	71 (25)	94 (33)	86 (30)	46 (16)	11 (2)	357
2661	CONSTANTINE RESERVOIR	71 (25)	83 (29)	40 (14)	29 (9)	3 (1)	90 (31)	316
2669	FORD LAKE	34 (12)	29 (10)	11 (4)	29 (9)	37 (13)	23 (8)	163
2671	FREMONT LAKE	0 (0)	0 (0)	23 (8)	54 (19)	9 (3)	11 (2)	97
2680	JORDAN LAKE	11 (4)	11 (4)	6 (2)	69 (24)	26 (9)	0 (0)	123
2683	KENT LAKE	57 (20)	69 (24)	63 (22)	40 (14)	6 (2)	36 (12)	271
2688	LAKE MACATAWA	9 (3)	14 (5)	3 (1)	0 (0)	23 (8)	43 (15)	92
2689	MANISTEE LAKE	80 (28)	74 (26)	77 (27)	46 (16)	80 (28)	46 (16)	403
2699	MUSKEGON LAKE	37 (13)	40 (14)	54 (19)	60 (21)	69 (24)	11 (2)	271
2705	PENTWATER LAKE	69 (24)	63 (22)	51 (18)	66 (23)	31 (11)	11 (2)	291
2711	RANDALL LAKE	6 (2)	6 (2)	43 (15)	23 (8)	20 (7)	86 (30)	184
2712	ROGERS POND	74 (26)	66 (23)	86 (30)	63 (22)	77 (27)	51 (18)	417
2713	RUSS RESERVOIR	60 (21)	57 (20)	57 (20)	9 (3)	63 (22)	79 (28)	345
2714	SANFORD LAKE	86 (30)	80 (28)	74 (26)	20 (7)	43 (15)	71 (25)	374
2723	THORNAPPLE LAKE	54 (19)	46 (16)	9 (3)	51 (18)	40 (14)	49 (17)	249
2725	UNION LAKE	40 (14)	26 (9)	26 (9)	37 (13)	34 (12)	79 (28)	242
2728	WHITE LAKE	66 (23)	60 (21)	66 (23)	80 (28)	74 (26)	31 (11)	377
2691	MONA LAKE	3 (1)	3 (1)	37 (13)	43 (15)	17 (6)	20 (7)	123
2692	LONG LAKE	14 (5)	9 (3)	46 (16)	77 (27)	66 (23)	27 (9)	239

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	FALL VALUES: MEAN TOTAL P	FALL VALUES: MEAN DISS P	FALL VALUES: MEAN INORG N	ALL VALUES: 500-MEAN SEC	ALL VALUES: MEAN CHLORA	ALL VALUES: 15-MIN DO	INDEX NO
2693	ST LOUIS RESERVOIR	1 (6)	17 (6)	29 (10)	14 (5)	83 (29)	69 (24)	229
2694	CRYSTAL LAKE	89 (31)	89 (31)	89 (31)	89 (31)	91 (32)	36 (12)	483
2695	HIGGINS LAKE	94 (33)	94 (33)	97 (34)	97 (34)	97 (34)	57 (20)	536
2696	HOUGHTON LAKE	83 (29)	86 (30)	91 (32)	71 (25)	71 (25)	79 (26)	481
2697	THOMPSON LAKE	51 (18)	49 (17)	60 (21)	83 (29)	51 (18)	11 (2)	305
2698	PERE MARQUETTE LAKE	63 (22)	51 (18)	71 (25)	49 (17)	54 (19)	66 (23)	354
2699	STRAWBERRY LAKE	43 (15)	34 (12)	49 (17)	74 (26)	57 (20)	27 (9)	284

APPENDIX B

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR MICHIGAN 2/3/75

LAKE CODE 2685 UNION LAKE

TOTAL DRAINAGE AREA OF LAKE(SQ MI) 534.00

TRIBUTARY	SUB-DRAINAGE AREA(SQ MI)	NORMALIZED FLOWS(CFS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
2685A1	534.00	419.00	543.00	598.00	760.00	489.00	339.00	235.00	151.00	131.00	190.00	264.00	434.00	378.14
2685A2	530.00	416.00	539.00	593.00	754.00	485.00	336.00	233.00	150.00	130.00	188.00	262.00	430.00	375.06
2685ZZ	4.00	3.20	4.10	4.50	5.70	3.70	2.50	1.80	1.10	1.00	1.40	2.00	3.30	2.85

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 534.00
SUM OF SUB-DRAINAGE AREAS = 534.00

TOTAL FLOW IN = 4550.29
TOTAL FLOW OUT = 4553.00

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2685A1	10	72	281.00	29	354.00				
	11	72	549.00	26	654.00				
	12	72	744.00	17	1010.00				
	1	73	1060.00	21	755.00				
	2	73	572.00	20	485.00				
	3	73	1020.00	25	1240.00				
	4	73	992.00	15	839.00	29	868.00		
	5	73	660.00	13	512.00	27	906.00		
	6	73	733.00	24	405.00				
	7	73	277.00	28	261.00				
	8	73	283.00	28	173.00				
	9	73	119.00	28	113.00				
2685A2	10	72	279.00	29	351.00				
	11	72	544.00	26	649.00				
	12	72	738.00	17	1000.00				
	1	73	1050.00	21	749.00				
	2	73	568.00	20	481.00				
	3	73	1010.00	25	1230.00				
	4	73	984.00	15	832.00	29	861.00		
	5	73	655.00	13	508.00	27	899.00		
	6	73	727.00	24	402.00				
	7	73	275.00	28	259.00				
	8	73	280.00	28	172.00				
	9	73	118.00	28	112.00				
2685ZZ	10	72	2.10						
	11	72	4.10						
	12	72	5.60						
	1	73	8.00						
	2	73	4.30						
	3	73	7.70						
	4	73	7.40						
	5	73	5.00						
	6	73	5.50						
	7	73	2.10						
	8	73	2.10						
	9	73	0.90						

APPENDIX C

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 75/02/04

268501
42 03 00.0 085 12 00.0
UNION LAKE
26 MICHIGAN

11EPALES 2111202
5 0014 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/14	10 49	0000	21.0	8.4	33	530	8.28	208	0.240	0.060	0.038	0.022
	10 49	0014	19.8	6.8		480	7.98	216	0.320	0.120	0.059	0.031
72/09/16	12 25	0000			60	500	7.98	167	0.650	0.080	0.054	0.023
	12 25	0004	18.0	8.4		500	8.00	167	0.630	0.080	0.047	0.022
72/11/12	09 30	0000			72	540	7.90	196	0.940	0.320	0.078	0.053
	09 30	0004	6.9	10.0		540	7.90	202	0.940	0.320	0.073	0.056
	09 30	0008	6.9	10.0		540	7.90	226	0.960	0.310	0.088	0.067
	09 50	0000						204	0.940	0.280	0.095	0.079

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/14	10 49	0000	26.7J
72/09/16	12 25	0000	3.7J
72/11/12	09 30	0000	5.2J

J VALUE KNOWN TO BE IN ERROR

STORET RETRIEVAL DATE 75/02/04

268502
42 03 30.0 085 10 00.0
UNION LAKE
26 MICHIGAN

11EPALES 2111202
5 0006 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/14	11 13	0000	22.8	11.2	30	480	8.33	208	0.320	0.040	0.036	0.017
	11 13	0006	22.5	10.8		560	8.29	206	0.290	0.030	0.038	0.017
72/09/16	13 25	0000			36	480	8.45	163	0.050	0.060	0.041	0.014
	13 25	0004	19.2	9.0		460	8.43	168	0.080	0.070	0.033	0.012
	13 25	0012	19.2	8.2		480	8.35	166	0.080	0.080	0.037	0.012
72/11/12	09 50	0000	7.0	10.0	36	540	7.80					

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/14	11 13	0000	34.6J
72/09/16	13 25	0000	22.6J
72/11/12	09 50	0000	1.2J

J VALUE KNOWN TO BE IN ERROR

APPENDIX D

TRIBUTARY DATA

STORET RETRIEVAL DATE 75/02/04

2685A1 LS2685A1
42 02 30.0 085 12 30.0
ST JOSEPH RIVER
26 15 UNION CITY
U/UNION LAKE
BRDG CONNECTING DUNES RD AND BLOSSOM RD
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	15 40		0.810	2.350	0.198	0.029	0.092
72/11/26	13 50		1.010	0.630	0.138	0.058	0.086
72/12/17	13 50		1.220	2.940	0.147	0.019	0.044
73/01/21	11 50		1.060	1.150	0.074	0.012	0.025
73/02/20	20 20		1.220	0.630	0.021	0.006	0.040
73/03/25	12 50		0.740	0.720	0.006	0.005K	0.035
73/04/15	13 10		0.820	0.750	0.024	0.005K	0.030
73/04/29	14 20		0.530	1.760	0.042	0.009	0.055
73/05/13	12 30		0.560	0.930	0.016	0.014	0.050
73/05/27	09 20		0.620	0.920	0.030	0.013	0.050
73/06/24	12 00		0.490	1.030	0.080	0.021	0.065
73/07/28	10 30		0.154	0.940	0.038	0.013	0.060
73/08/28	20 20		0.315	0.690	0.037	0.005K	0.045
73/09/28	21 20		0.560	0.570	0.026	0.008	0.030

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

2645A2 LS2685A2
42 04 00.0 085 09 30.0
ST JOSEPH RIVER
26 15 UNION CITY
1/UNION LAKE
ARBORGAST RD 1 MI W UNION CITY BELOW STP
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	15 30		0.840	0.900	0.290	0.075	0.110
72/11/26	13 25		0.930	1.260	0.138	0.058	0.086
72/12/17	13 20		0.660	2.200	0.072	0.018	0.063
73/01/21	11 20		1.120	4.500	0.290	0.015	0.030
73/02/20	20 50		1.240	0.720	0.072	0.009	0.050
73/03/25	12 30		0.760	0.750	0.006	0.007	0.035
73/04/15	12 40		0.780	1.600	0.072	0.008	0.030
73/04/29	13 50		0.560	1.800	0.078	0.015	0.045
73/05/13	12 00		0.690	0.720	0.024	0.020	0.050
73/05/27	08 30		0.660	0.995	0.037	0.024	0.060
73/06/24	11 40		0.740	1.500	0.073	0.031	0.075
73/07/28	10 05		0.840	0.660	0.034	0.027	0.065
73/08/28	19 50		0.670	0.440	0.011	0.011	0.052
73/09/24	20 45		0.880	0.650	0.058	0.019	0.040

STORET RETRIEVAL DATE 75/02/04

```
 26M5AJ           LS26M5AJ
42 04 00.0 085 08 30.0
ST JOSEPH RIVER
26       15 UNION CITY
I/UNION LAKE
* BRDG IN UNION CITY ABOV STP
11EPALES                2111204
4                       0000 FEET  DEPTH
```

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	15 15		0.770	0.750	0.231	0.075	0.105
72/11/26	12 50		0.990	1.400	0.126	0.058	0.084
72/12/17	12 40		1.160	0.840	0.040	0.019	0.044
73/01/21	11 00		1.100	0.540	0.056	0.015	0.025
73/02/20	20 20		1.220	0.630	0.035	0.010	0.050
73/03/25	12 10		0.760	0.710	0.005K	0.007	0.035
73/04/15	12 10		0.770	2.310	0.092	0.009	0.025
73/04/29	13 30		0.560	0.760	0.050	0.016	0.060
73/05/13	11 30		0.690	0.720	0.032	0.021	0.055
73/05/27	07 00		0.660	1.050	0.036	0.025	0.060
73/06/24	11 10		0.730	0.970	0.050	0.032	0.095
73/07/28	09 45		0.840	0.990	0.030	0.029	0.110
73/08/28	19 30		0.690	1.200	0.008	0.015	0.045
73/09/28	20 15		0.790	0.500	0.058	0.012	0.035

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 73/02/04

264581 LS2685H1
42 04 00.0 085 09 00.0
COLDWATER RIVER
26 15 UNION CITY
1/UNION LAKE
EAST BRDG IN UNION CITY
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	15 05		0.760	1.650	0.450	0.126	0.160
72/11/26	12 00		0.960	0.800	0.210	0.096	0.120
72/12/17	11 40		1.080	1.760	0.084	0.023	0.034
73/01/21	10 45		1.140	0.920	0.086	0.019	0.030
73/02/20	19 50		1.150	0.580	0.030	0.007	0.040
73/03/25	11 50		0.820	0.880	0.013	0.007	0.045
73/04/15	11 40		0.890	2.310	0.094	0.008	0.030
73/04/29	13 10		0.670	0.920	0.053	0.015	0.060
73/05/13	11 00		0.690	0.700	0.040	0.019	0.045
73/05/27	08 00		0.580	0.920	0.042	0.020	0.045
73/06/24	10 40		0.590	0.940	0.065	0.027	0.075
73/07/28	09 10		0.710	0.910	0.035	0.019	0.035
73/08/28	19 10		0.610	0.540	0.016	0.008	0.045
73/09/28	19 45		0.780	1.050	0.084	0.009	0.035